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Power supply

Lecture No 3

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Lecture 3.
Basic concepts and facts about heating systems, heat load calculation

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Content of Lecture No 3

1. Characteristics of heating systems;
2. Calculation of heat power of heating system, heat losses through envelope, infiltration;
3. Heaters: types, selection.

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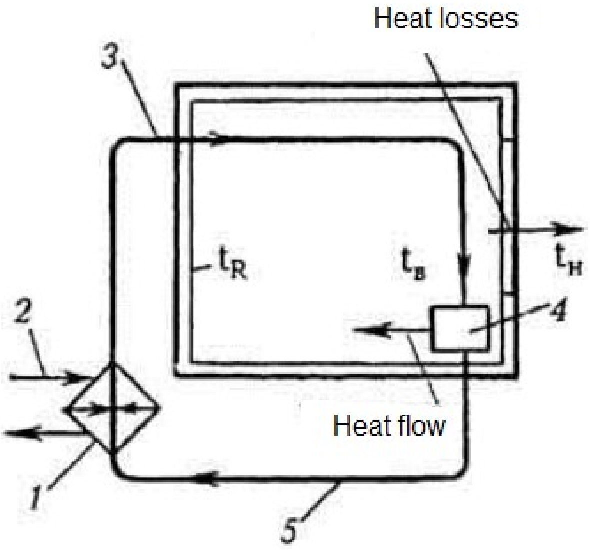
Main elements of heating system:

- Heat source (heat generator in local system or heat exchanger in centralized system);
- Heat pipeline;
- Heaters.



1 – heat generator or heat exchanger;
2 – fuel supply or primary coolant;
3 – flow heat pipeline;
4 – heater;
5 – return heat pipeline.

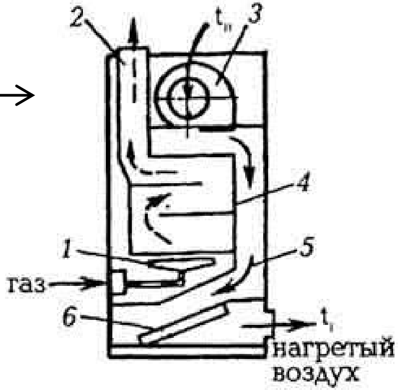
Requirements imposed to the heating systems:

- **Sanitary and hygienic**: maintaining the specified air temperature and internal surfaces of the envelopes of the room in time with permissible air mobility, limiting the temperature on the surface of the heaters;
- **economic**: optimal capital investments, economical consumption of heat energy during operation;
- **architectural and construction**: correspondence to the interior of the room, compactness, coordination with building structures, coordination with the construction period of the building;
- **production and installation**: the minimum number of unified units and parts, the mechanization of their manufacture, the reduction of labor costs and manual labor during installation;
- **operational**: the effectiveness of the action during the entire period of operation, reliability (reliability, durability, maintainability) and technical excellence, safety and quiet operation.

Classification of heating systems:

1) According to location of the main elements:
- Local;
- Central

gas-air heating unit



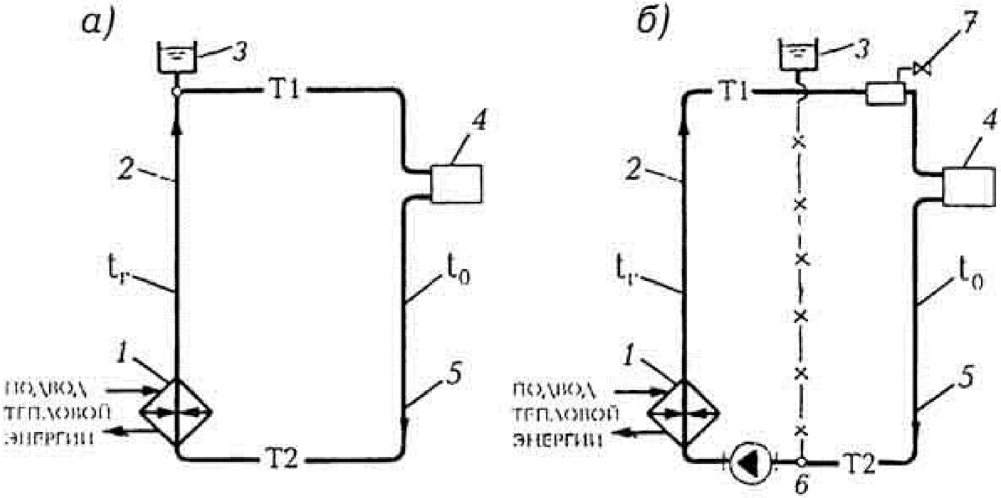
Heat pipelines of central systems:
- Main lines (flow, return);
- Risers (vertical pipes);
- Branches (horizontal pipe).

2) According to the heat carrier in the heating system:

- Gas produced by burning fuel;
- Air;
- Water;
- Steam.

3) According to type of circulation in water heating system:

- Gravitational
- Pumping.



With natural circulation (gravitational) | Pumping

1 – heat exchanger; 2 – flow pipeline; 3 – expansion tank; 4 – heater; 5 – return pipeline; 6 – circulating pump; 7 – device for air removing from the system.

4) According to temperature of heat carrier in water heating system:

- Low temperature (t<70°C);
- Medium temperature (70<t<100°C);
- High temperature (t>100°C).

5) According to pipe arrangement in the building:

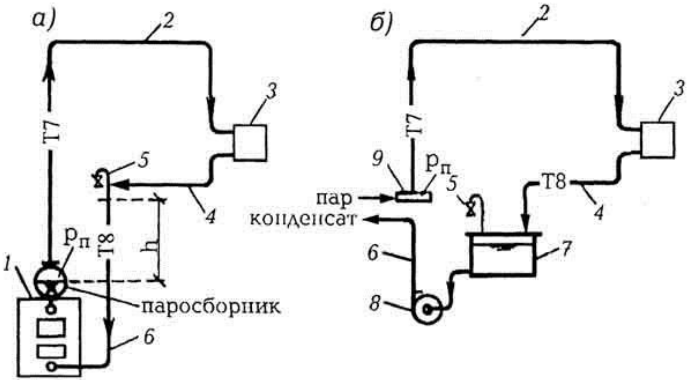
- Vertical;
- Horizontal.

6) Depending on the scheme of connection of pipes with heating devices of the system:

- single-tube;
- two-tube.

7) According to the way of condensate return in steam heating systems:

- Closed;
- Open.



a is a closed circuit; b is open circuit; 1 - steam boiler with a steam collector; 2 - steam line (T7); 3 - the heater; 4 and 5 - gravity and pressure condensate lines (T8); 6 - air outlet pipe; 7 - condensing tank; 8 - condensate pump; 9 - steam distribution collector.

Thermal equilibrium of a room:

$$\boxed{Q_h = \Delta Q = Q_{env} + Q_{inf} \pm Q_{t/d}, W}$$

Q_h is a heat power of the heating system;

ΔQ is a deficit of heat;

Q_{env} are heat losses through envelope;

Q_{inf} is heat consumption for heating outside air entering the room (infiltration);

$Q_{t/d}$ are technological or domestic heat emissions or heat consumption.

The main heat losses in the room through the envelope:

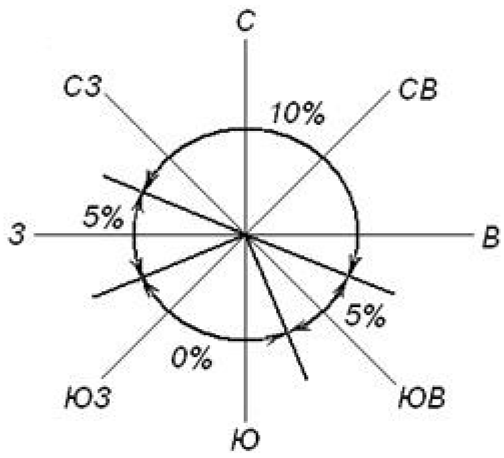
$$\boxed{Q_{env} = A / R \cdot \left(t_{int}^{p} - t_{h}^{p}\right) \cdot \left(1 + \sum \beta_i\right) \cdot n, MW}$$

A is the predicted area of the envelope, m^2;
R is the resistance to the heat transfer of the envelope, (m^2 ·°C)/W;
β is the additional heat losses in fractions from the main for various types of rooms and envelopes;
n is the coefficient adopted for the envelopes separating the heated room from unheated.

Additional heat losses

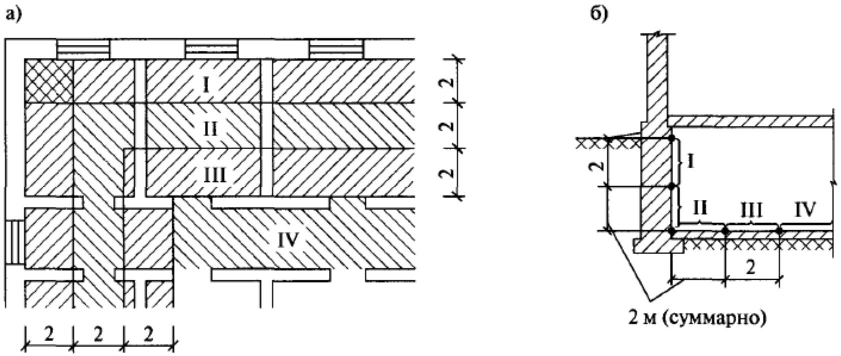
$$Q_{env} = A / R \cdot \left(t_{int}^{p} - t_{h}^{p}\right) \cdot \left(1 + \sum \beta_{i}\right) \cdot n, MW$$

- Additive on orientation according to cardinal point



- Additive on cold outside air leakage through exterior doors.

Calculation of heat losses through the floor lying on the ground



- Resistances of uninsulated floor:

Zone I $R_{I} = 2{,}1$ м^2•°C/Вт;
Zone II $R_{II} = 4{,}3$ м^2•°C/Вт;
Zone III – $R_{III} = 8{,}6$ м^2•°C/Вт;
Zone IV – $R_{IV} = 14{,}2$ м^2•°C/Вт.

- Resistances of insulated floor:

$$R_{у.п} = R_{н.п} + \sum \frac{\delta_{у.с}}{\lambda_{у.с}},$$

thickness of insulated material

thermal conductivity coefficient of insulated material

resistance to heat transfer of uninsulated floor, (m^2 °C)/W.

resistance to heat transfer of insulated floor, (m^2 °C)/W.

$$Q_{env} = A / R \cdot \left(t_{int}^{p} - t_{h}^{p}\right) \cdot \underbrace{\left(1 + \sum \beta_i\right)}_{=1} \cdot n, \text{MW}$$

- Resistances of floor on ground joist (пол на лагах):

R=1,18 Ry.п

Floor on ground joist

Heat loss for heating the infiltration air

$$Q_{inf} = 0.28 L_{vent} \rho_{out} c \left(t_{int}^{p} - t_{h}^{p} \right),$$

The specific air flow rate for residual buildings according to norms:

L_{vent}=3 m^3 /hour for 1 m^2 of the area of residual buildings and kitchen;

ρ_{out} is density of outside air, kg/ m^3;

c is mass heat capacity of outside air, 1kJ/(kg ·°C);

0.28 is numeral coefficient adjusting the accepted dimensions of air flow rate, kg/hour, and heat flow, W (0.28=1005/3600).

Calculation of heat power of heating system

Thermal equilibrium of a room $$Q_h = \Delta Q = Q_{env} + Q_{inf} \pm Q_{t/d}, W$$

Heat power of heating system $$Q_h = k(\sum \Delta Q)\beta_1 \beta_2,$$

k is correction coefficient that takes into account additional heat loss associated with heat carrier cooling in the main lines passing in unheated rooms (when laying both lines in the underground or basement k = I, 03; when laying one of the line in the attic k = I, I); β1 - coefficient of accounting for additional heat flow of heating devices due to rounding of their area in excess of the calculated value; β2 - coefficient of accounting for additional heat losses by heaters located at external envelope.

If there is no necessary data - kβ1β2 = I.07

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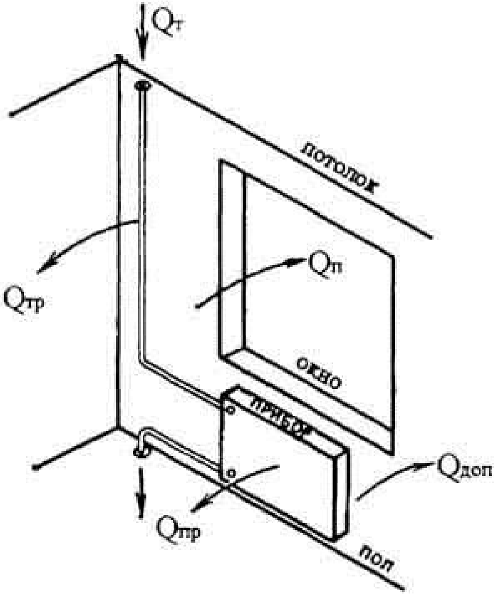
$Q_{hl} = Q_{пр} + Q_{тр}.$

Heat from pipes in a room

Heat from heaters

Heat losses



Flow rate of water in the system: $G_{вод} = Q_{hl} / (c(t_{вх} - t_{вых})).$

water temperature
at the input to the heating system

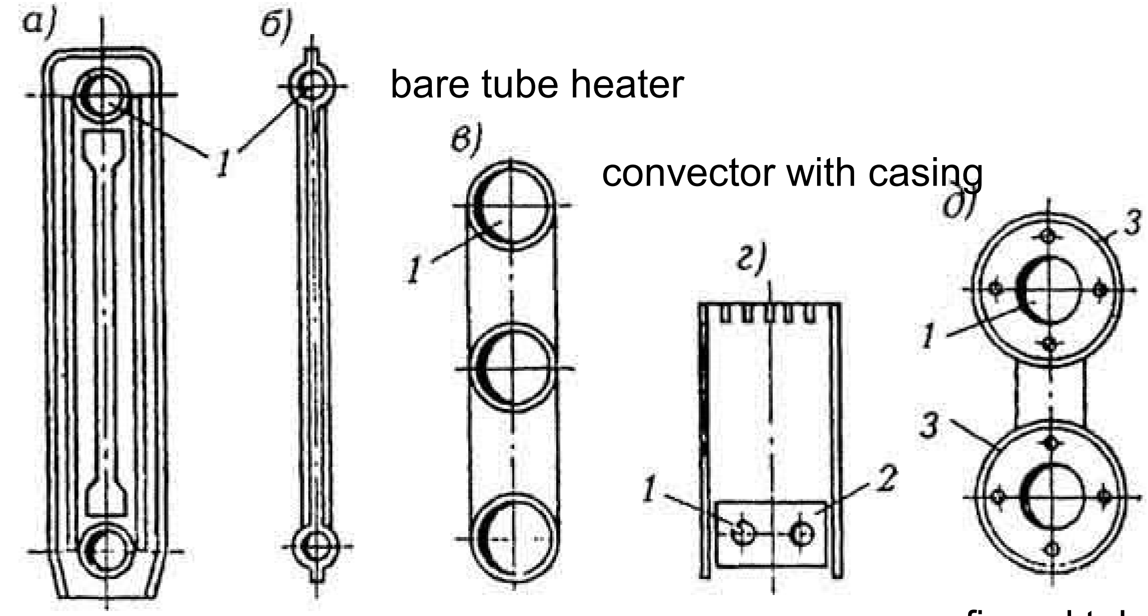
output

Flow rate of steam in the steam heating system: $G_{пар} = Q_{hl} / r.$ phase transition heat

Classification:

1. According to heat transfer mechanism:

- Radiation - at least 50% of the total heat flux by radiation
- Convective-radiation - from 50 to 75% by convection
- Convective – at least 75% by convection

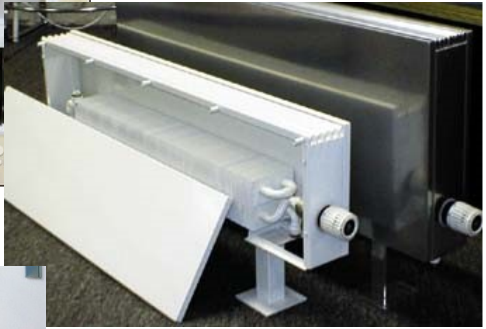


sectional and panel radiators

finned tube

Radiators

Convectors

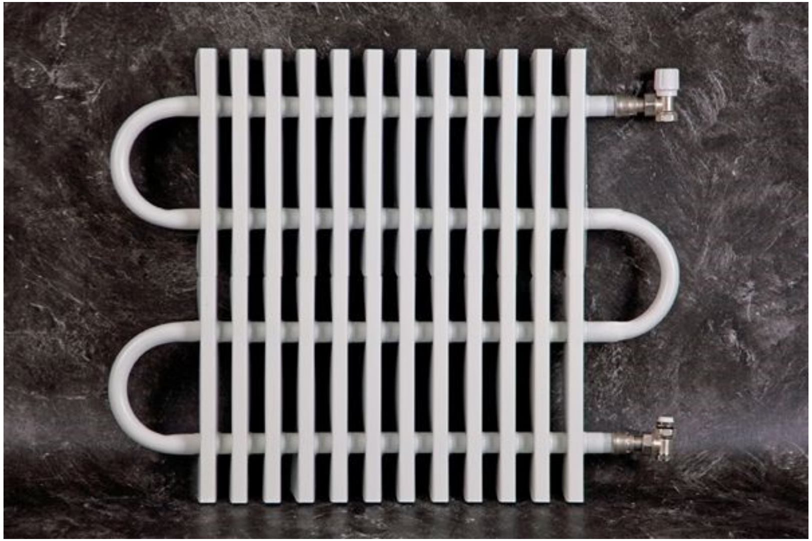


2. According to the material used

- metal,
- combined
- and non-metallic heaters

3. According the magnitude of thermal inertia:

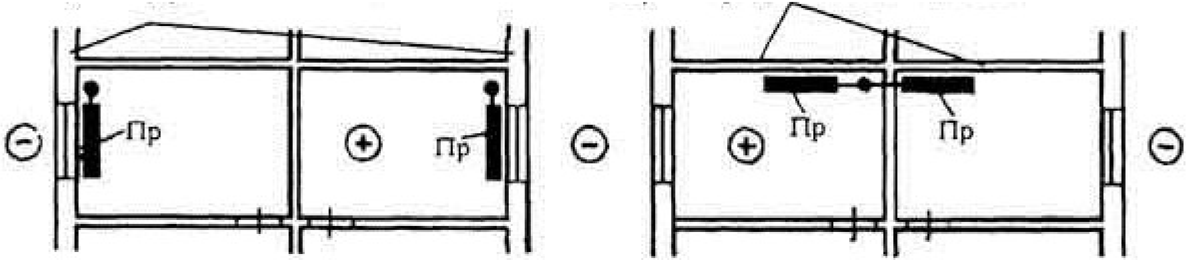
- Small
- and Large inertia heaters.



Selection and placement of heaters

Outer walls

Inner walls



Air circulation when heaters are installed:

under windows
without a windowsill

under windows
with a windowsill

near the inner wall

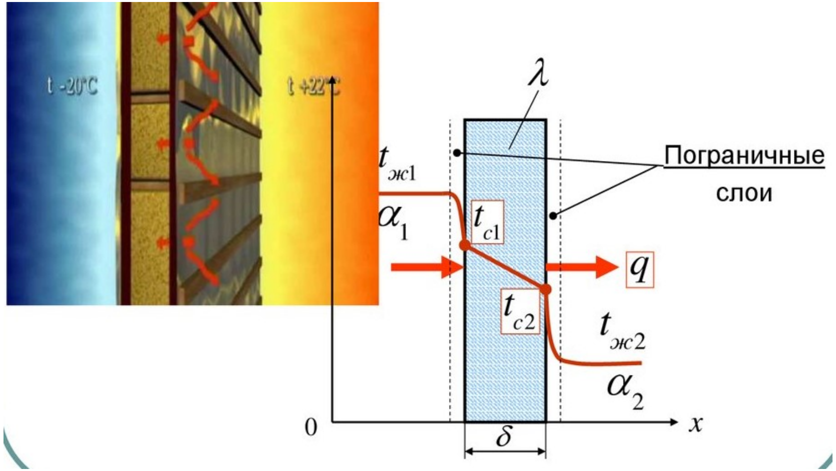
Placement of heaters in staircases

Thermal calculation of heaters

1. Overall heat transfer coefficient $k_{пр} = 1 / R_{пр}.$

Resistance to the heat transfer $R_{пр} = R_{в} + R_{ст} + R_{н}.$

- $R_{в}$ — resistance to the heat exchange on the inner surface of the heater wall
- $R_{ст}$ — thermal resistance of the wall
- $R_{н}$ — resistance to the heat exchange on the external surface of the heater wall



Empirical formula for calculation of the overall heat transfer coefficient: $k_{пр} = m\Delta t_{ср}{}^{n} G_{отн}{}^{p}$,

m, n, p – experimental coefficient expressing the influence of the structural and hydraulic features of the heater on its heat transfer coefficient ;

Temperature drop: $\Delta t_{ср} = t_{ср} - t_{в} = 0{,}5(t_{вх} + t_{вых}) - t_{в}$; air temperature inside a room

water temperature at the input to the heater

output of the heater

Relative water flow rate: $G_{отн} = G_{пр} / 360.$

The heat flux density $\boxed{q = k_{пр}\Delta t_{ср} = (m\Delta t^{n}_{ср} G^{p}_{отн})\Delta t_{ср} = m\Delta t_{ср}{}^{1+n} G^{p}_{отн}.}$

Temperature drop for single-pipe heating system: $t_{пр} = t_{вх} - 0{,}5\Delta t_{пр} = t_{вх} - 0{,}5Q_{пр}\beta_1\beta_2 / (cG_{пр}),$

heat load of the heater

β1 - correction factor, taking into account heat transfer through the additional area (in excess of the calculated) of the heaters (for radiators and convectors β1 = 1.03 ... 1.08, for ribbed pipes β1 = I, 13); β2 - correction factor that takes into account additional heat losses due to the placement of heating devices at external walls (a sectional radiator or convector KN и KO-types - β2 = 1,02, KA convector - 1,03, panel radiator - 1.04).

Temperature drop for two-pipe heating system: $t_{ср} = 0,5(t_{вх} + t_{вых}) = 0,5(t_г + t_о),$

Nominal heat flux density is calculated at $\Delta t_{ср} = 0,5(105 + 70) - 18 = 69,5 \approx 70\ °C,$ $G_{НОМ}$=360 kg/h or 0.1 kg/sec

If we know the nominal heat flux density, the calculated heat flux density of the heater:

$$q_{пр} = q_{ном}(\Delta t_н / 70)^{1+n}; \qquad q_{пр} = q_{ном}(\Delta t_{ср} / 70)^{1+n}(G_{пр} / 360)^p.$$

Nominal heat flux density for different types of heaters, W/m^2 :

Cast-iron sectional radiator (type MS-90-108)	-	790
Steel panel radiator (type RSV)	-	730
Cast-iron sectional radiator (type M-140 AO)	-	595
Convector with casing (type Universal-20)	-	357
Ribbed cast-iron pipe	-	388

- Thermal calculation of heaters is to determine the area of the external heating surface of each heater, providing the necessary heat flow from the heat carrier to the room.

$$Q_{пр} = q_{пр}A_{р}. \Longrightarrow A_{р} = Q_{пр} / q_{пр},$$

Required heat transfer of the heater to the room: $Q_{пр} = Q_{п} - \beta_{тр}Q_{тр};$

$Q_{п}$ is heat demand of the room

$Q_{тр}$ is the total heat transfer of the heated pipes (risers, branches) laid in the room;

$\beta_{тр}$ is the correction coefficient taking into account the heat transfer rate of the heat pipes, which is useful for maintaining the set room air temperature (βтр is in the case of laying pipes: open – 0.9, hidden in a hollow groove walls – 0.5, hardened in heavy concrete – 1.8).

Total heat transfer of the heated pipes: $Q_{тр} = q_{в}l_{в} + q_{г}l_{г}$

qв and qг - heat transfer of 1 m vertically and horizontally laid pipes, respectively, W/m, determined on the basis of their diameter and temperature difference (tт - tв); lв and lг are length of vertical and horizontal heat pipes, respectively, m.

Number of sections of radiator: $N = (A_{р} / a_{1})(\beta_{4} / \beta_{3}),$

a1 - area of one section, m^2; β4 - correction factor taking into account the method of installation of the radiator in the room (with open installation β4 = 1.0, when installing with a decorative casing β4≤1.10); β3 is a correction factor that takes into account the number of sections in one radiator (β3 = 1.0 for Ap = 2.0 m^2).

β3 for radiators of the M-140A type is calculated as: $\beta_3 = 0{,}97 + 0{,}06 / A_p$.

For types of radiator with an area of one section of 0.25 m^2 the coefficient β3 is determined by the formula:

$$\beta_3 = 0{,}92 + 0{,}16 / A_p.$$

The calculated number of sections is rarely obtained by an integer. When choosing an integer number of sections of the radiator, the calculated area Ap can be reduced by no more than 5% (but not more than 0.1 m2). This is done in order to limit the deviation from the design temperature in the room (usually a reduction of 1 ° C in civil and 2 ° C in industrial premises is acceptable). Therefore, as a rule, a large number of sections are accepted for installation.

Number of steel panel radiators: $N = A_p / a_1$.

Number of elements of convectors without casing or ribbed pipes: $N = A_p / (na_1)$

n is the number of tiers (ярусов) and rows (рядов) of elements making up the heater; a1 - the area of one element of the convector or one ribbed pipe of the adopted length, m^2 .

Length of pipe in the tier or row of bare-tube heater: $l = A_p\beta_4 / (na_1)$,

β4 - correction factor, taking into account the presence of decorative cover of pipes; n - number of tiers or rows of heating pipes that make up the heater; a1 - area of 1 m of open horizontal pipe of accepted diameter, m^2 / m.

When rounding the fractional calculated number of elements or devices to an integer, it is admissible, as for radiators, to reduce Ap by no more than 5% (but not more than 0.1 m^2).

Example

Determine the number of sections of a cast iron radiator of the M-140A type installed on the top floor near the outer wall (at a distance of 40 mm from windowsill) in a 2.7 m high room with a heat demand of the room of Qn = 1410 W and tB = 18 ° C. The radiator is connected to a single-tube riser Dy20 (with a three-way valve KRT type with 0.4 m piping), a water heating system with an overhead wiring at tг = 105 ° C and a water flow in the riser Gst = 300 kg / h. The water in the supply line is cooled by 2 ° C (up to considered riser).

Average temperature of water in the heater: $t_{пр} = t_{вх} - 0{,}5\Delta t_{пр} = t_{вх} - 0{,}5Q_{пр}\beta_1\beta_2 / (cG_{пр}),$

$$t_{ср} = (105 - 2) - 0{,}5 \cdot 1410 \cdot 1{,}06 \cdot 1{,}02 \cdot 3{,}6 / (4{,}187 \cdot 300) = 100{,}8\ °C.$$

The density of the heat flux of the radiator at Δtcp = 100,8 - 18 = 82,8 ° C:

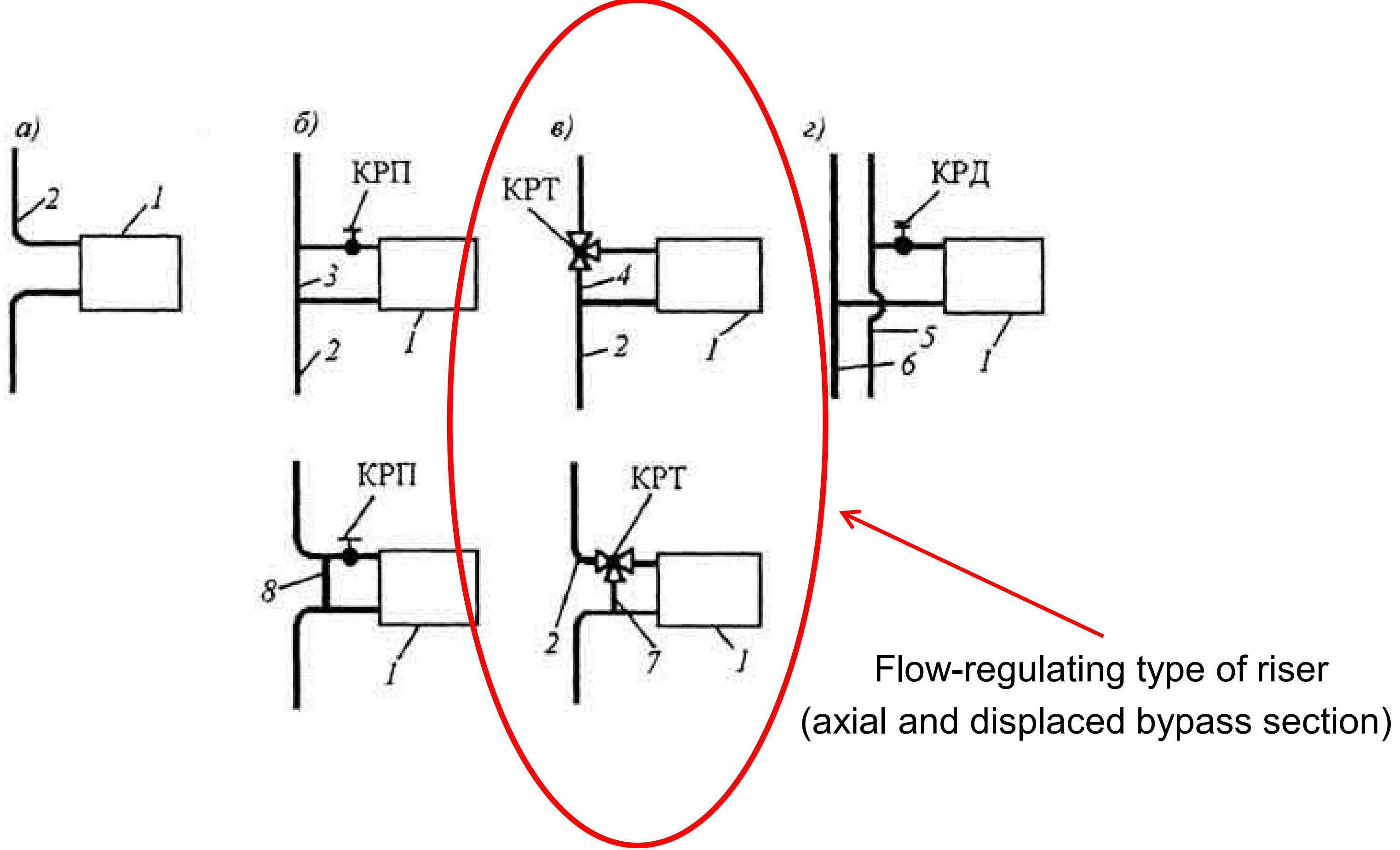
$q_{пр} = 650(82{,}8 / 70)1{+}0{,}3 = 809$ Вт/м^2. where n=0.3

Heat transfer from vertical (tв = 2,7 - 0,5 = 2,2 м) and horizontal (tг= 0,8 м) pipes Dy20: $Q_{тр} = 93 \cdot 2{,}2 + 115 \cdot 0{,}8 = 296$ Вт.

Calculated area of the radiator: Ap= (1410 - 0,9*296) / 809 = 1,41 м2.

$N = (A_p / a_1)(\beta_4 / \beta_3),$ β3 = 0,97 + 0,06 / 1,41= 1,01, β4=1,05

$N = (1{,}41 / 0{,}254)(1{,}05 / 1{,}01) = 5{,}8$ секции.



а)
б)
в)
г)
КРП
КРТ
КРД
КРП
КРТ
1
2
3
4
5
6
7
8
Flow-regulating type of riser
(axial and displaced bypass section)

Practice No 6
To the selection and calculation of heaters

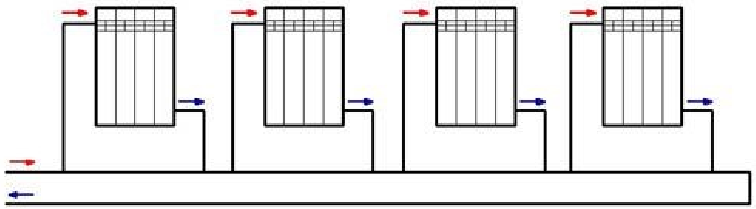
Selection of heating system

According to pipe arrangement in the building:
- Vertical;
- Horizontal.

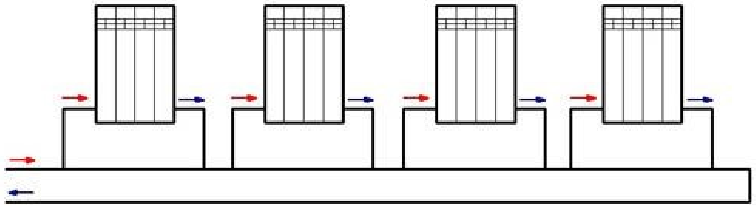
Depending on the scheme of connection of pipes with heating devices of the system:
- single-tube;
- two-tube.

According to direction of water movement in flow and return lines of two-tube systems:
- In one direction;
- In other directions.

- single-tube;



Однотрубная сверху вниз



Однотрубная с нижним подключением

- two-tube

(with one and different directions of water movement)

Тупиковая схема движения теплоносителя

Попутная схема движения или петля "Тихельмана"

Plan of work

1. Calculation of heat losses through envelope + for infiltration = total heat losses for each room in the building;
2. Calculation of the area of the external heating surface of each heater ($q_в$ and $q_г$ are the reference data, take diameter of branches to the heaters: 15-20 mm):

$$A_p = Q_{пр} / q_{пр},$$

Required heat transfer of the heater to the room: $Q_{пр} = Q_п - \beta_{тр} Q_{тр};$

$Q_п$ is heat demand of the room

$Q_{тр}$ is the total heat transfer of the heated pipes (risers, branches) laid in the room;

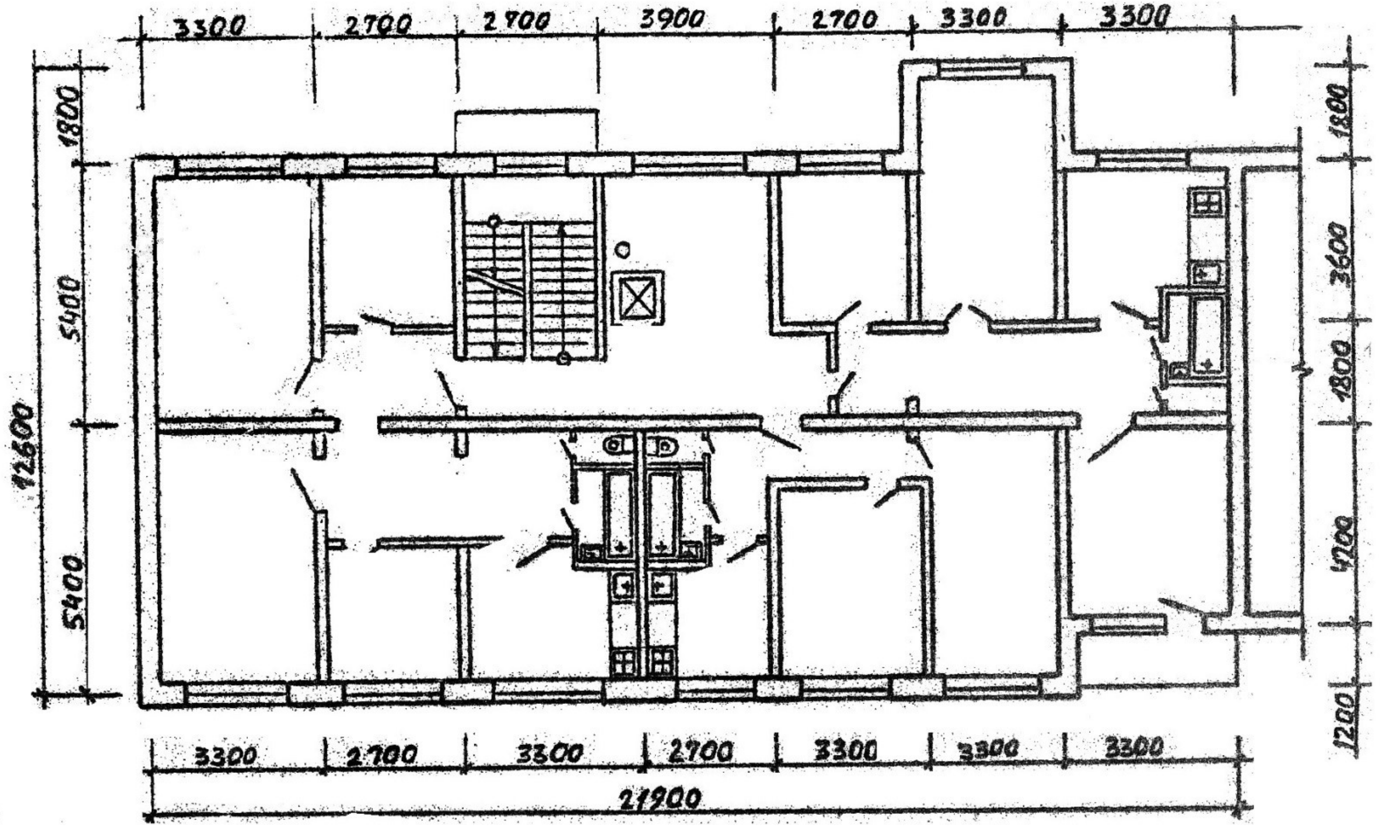
$\beta_{тр}$ is the correction coefficient taking into account the heat transfer rate of the heat pipes, which is useful for maintaining the set room air temperature ($\beta_{тр}$ is in the case of laying pipes: open – 0.9, hidden in a hollow groove walls – 0.5, hardened in heavy concrete – 1.8).

Total heat transfer of the heated pipes: $Q_{тр} = q_в l_в + q_г l_г$

$q_в$ and $q_г$ - heat transfer of 1 m vertically and horizontally laid pipes, respectively, W/m, determined on the basis of their diameter and temperature difference ($t_т$ - $t_в$); $l_в$ and $l_г$ are length of vertical and horizontal heat pipes, respectively, m.

3. Calculate number of sections for radiators and number of elements of convector (slides 23-24)

THANK
FOR YOUR
ATTENTION!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